INTRODUCTION

To the naked-eye, the night sky offers a quite misleading impression of the distribution of matter in the Universe around us. We see stars in every direction, and we could be excused for jumping to the erroneous conclusion that the cosmos is simply filled with a more-or-less uniform distribution of stars. We now recognize this view to be incorrect: stars are, in fact, distributed in vast stellar systems called galaxies, and we live within one such system – the Milky Way Galaxy. The starting point of this book is to study our own Galaxy, and then move on to consider galaxies in general. Equally importantly, we shall also discuss the astronomical techniques and the scientific reasoning that has led to our current view of galaxies. One finding of such studies is that the luminous output of the majority of galaxies is dominated by their stars, but there are exceptions to this rule: the so-called *active galaxies*, in which a huge luminosity is emitted from a region that is no bigger than our Solar System.

It took painstaking efforts by pioneering astronomers, most notably Edwin Hubble, to establish the existence of galaxies external to the Milky Way. However, once this leap had been made in the 1920s, the scene was set for an exploration of the Universe on ever larger scales. The picture that has emerged is that galaxies appear to be the 'building blocks' that make up the large-scale distribution of matter in the Universe. So, a question arises as to why the Universe is organized in this way – how, and why, do galaxies form? Although there are no simple answers to these questions, throughout this book we shall see how these problems are currently being tackled by astronomers.

Observations of galaxies play a key role in *cosmology* – the scientific study of the nature and evolution of the Universe as a whole. It was, again, Edwin Hubble who made the observations that revolutionized this field. His work led to the single most important result in cosmology: that the Universe is expanding – the distances between galaxies are increasing as time progresses. Once this idea is accepted, it is not difficult to deduce that in the past, galaxies must have been closer together. This idea is taken to its logical extreme in the idea of the *big bang* model: at some finite time in the past – about 14 billion years ago – the separation between objects in the Universe would have been extremely small, and ever since this time the Universe has been expanding. Later in this book we shall explore the reasoning behind, and the implications of, this model in much more detail. However, since the idea of the big bang plays such a fundamental role in modern astronomy and cosmology it is worth here highlighting a few of the key features of this model:

- The Universe has a finite age, which is currently estimated to be about 14 billion years.
- The Universe has been expanding since the very first instant of the big bang.
- The early stages of the evolution of the Universe were characterized by high temperatures and densities. Furthermore, at any given time, the density and temperature were highly, although not perfectly, uniform.
- Within the first few minutes of the big bang, nuclear reactions formed light nuclei. As a result, the fraction (by mass) of material in the Universe after these processes came to an end was about 76% hydrogen and 24% helium. A trace amount of lithium was also formed.

A surprising feature of modern astronomy is that much of cosmic history can be viewed directly. Light, and other forms of electromagnetic radiation, travels at the finite speed of $3 \times 10^8\,\mathrm{m\,s^{-1}}$. It takes about two million years for light to reach us from the nearby Andromeda Galaxy – so the images we make today actually show the appearance of this galaxy as it was two million years ago. Two million years is a very short time by cosmic standards, but the same principle applies to observations of much more distant galaxies. Current observations using the most sensitive telescopes can view galaxies as they appeared over ten billion years ago. Such studies are now allowing astronomers to piece together a picture of the formation and evolution of galaxies over the history of the Universe. And this is not the limit of our vision – we can also detect background radiation that gives us a view of the Universe as it appeared when it was only about 400 000 years old. This information is now allowing cosmologists to test theories that describe the Universe during the first few fractions of a second of the big bang.

In this book, we shall explore the implications of the latest observational techniques for astronomy and cosmology. We hope that in doing so, we will share with you some of the sense of excitement that a scientific study of the Universe can bring.

Note: It is assumed that readers of this book already have an understanding of the fundamental aspects of stellar astronomy and the processes of stellar evolution. These topics are dealt with in detail in the companion volume to this book – *An Introduction to the Sun and Stars*.